

MgB₂-BASED BOLOMETER ARRAY FOR FAR INFRA-RED THERMAL IMAGING AND FOURIER TRANSFORM SPECTROSCOPY APPLICATIONS. B. Lakew¹, S. Aslam^{1*}, J. Brasunas¹, ¹NASA, GSFC, Planetary Systems Laboratory, Greenbelt, MD 20771, USA, *e-mail contact: shahid.aslam-1@nasa.gov.

Introduction: The mid-superconducting critical temperature ($T_c \approx 39$ K) of the simple binary, inter-metallic MgB₂ [1] makes it a very good candidate for the development of the next generation of electro-optical devices (e.g. [2]). In particular, recent advances in thin film deposition techniques to attain high quality polycrystalline thin film MgB₂ deposited on SiN-Si substrates, with $T_c \approx 38$ K [3] coupled with the low voltage noise performance of the film [4] makes it highly desirable for the development of moderately cooled bolometer arrays for integration into future space-borne far infra-red (FIR) spectrometers and thermal mappers for studying the outer planets, their icy moons and other moons of interest in the 17-250 μ m spectral wavelength range. Presently, commercially available pyroelectric detectors operating at 300 K have specific detectivity, D^* , around 7×10^8 to 2×10^9 cm $\sqrt{\text{Hz/W}}$. However, a MgB₂ thin film based bolometer using a low-stress (< 140 MPa) SiN membrane isolated from the substrate by a small thermal conductive link, operating at 38 K, promises to have two orders of magnitude higher specific detectivity [5][6].

MgB₂-based Bolometer Array: The fabrication process consists essentially of, (i) photolithography of the MgB₂ layer into arrays of sensor elements, wiring and pads; (ii) photolithography and partially etching the SiN layer into membranes, legs, and dicing streets; (iii) bonding the front side of the wafer to a Pyrex wafer using wax; (iv) patterning and removing back side nitride and oxide layers; (v) backside deep reactive ion etching of openings and streets in the silicon substrate down to the front oxide layer; (vi) wet etch the front oxide through the new openings and streets to reveal the nitride membranes; (vii) dry etching of the remaining front nitride and finally releasing the chips in non-aggressive solvent. A photograph of the fabricated 10 x 10 MgB₂ thin-film array together with one of the bolometer pixel geometries is shown in Figure 1.

Cooling Technology: If a MgB₂ thin-film bolometer is to be used on future planetary missions, the focal plane assembly will need to be cooled down to 20 K [7], a temperature range not practically attainable with passive radiative coolers. The focal plane will have to be paired with a lightweight low power mechanical cryocooler. Even though cryocoolers are now used on missions such as the Hubble Space Telescope and are

in development for the James Webb Space Telescope and other missions, there are no space-qualified cryocoolers that presently satisfy the stringent mass and power requirements for outer planet missions. However, substantial efforts are currently underway in both commercial companies, e.g. Sunpower Inc. (<http://www.sunpower.com>) and Ricor USA Inc. (<http://www.ricor.com>) and government agencies, e.g. NASA, to develop advanced cooling technologies that will meet the requirements to cool MgB₂ bolometer focal plane assemblies and be compatible for use in space.

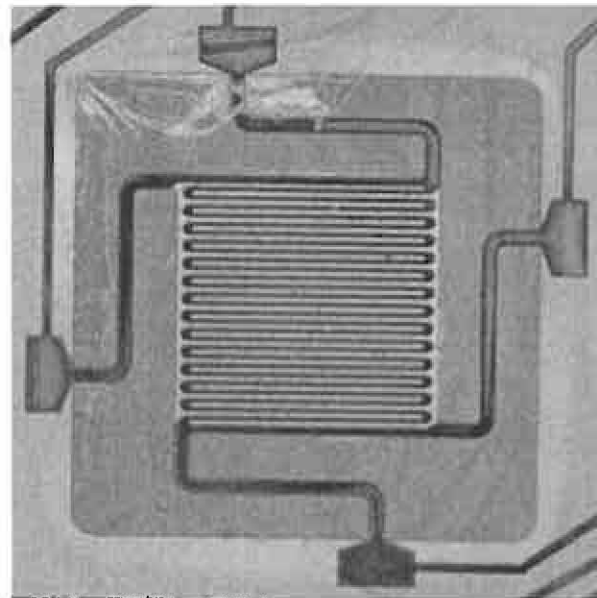
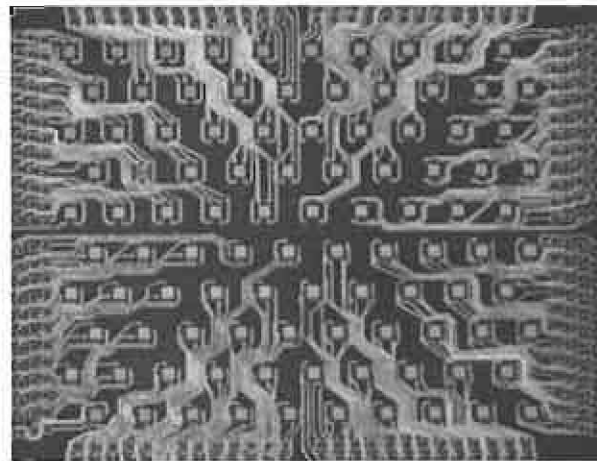


Figure 1. 100-pixel MgB_2 bolometer array and a single pixel with size $250\text{ }\mu\text{m} \times 250\text{ }\mu\text{m}$ with leg length $250\text{ }\mu\text{m}$ and leg width $14\text{ }\mu\text{m}$. The MgB_2 meander width is $10\text{ }\mu\text{m}$.

$R(T)$ Analysis: Figure 2, shows the $5\text{ }\mu\text{A}$ current bias $R(T)$ curve for corrected substrate temperature, together with dR/dT calculated from a functional curve fit to the data. The temperature, T_m and resistance, R_m , at the mid-point of the superconducting transition is 36.47 K and $1634\text{ }\Omega$ respectively, with a superconducting transition width, ΔT , of 0.35 K determined using the 10% - 90% of R_{40K} rule. The maximum temperature coefficient of resistance is $\alpha_{\text{max}} = 8.4\text{ K}^{-1}$, and at mid-point of transition $\alpha_{\text{mid}} = 5.8\text{ K}^{-1}$, the residual resistance ratio is, $\text{RRR} = R_{300K} / R_{40K} = 1.7$.

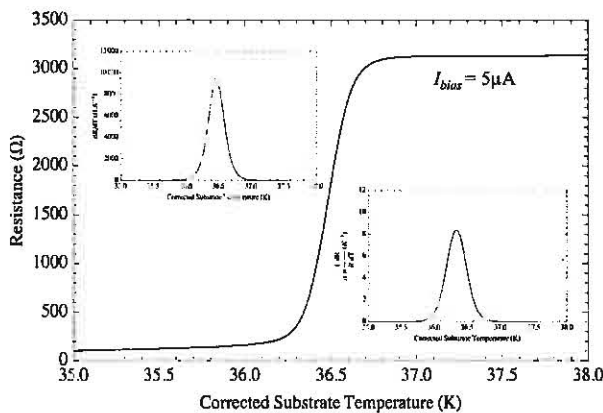


Figure 2. R , dR/dT and α as a function of corrected substrate temperature.

Responsivity: From load curve analysis, the electrical responsivity is 702 kV/W . Figure 3 shows a plot of voltage responsivity, $\mathcal{R}_{v,e}$, as a function of frequency to a 763 K blackbody source. The effective time constant is 5.2 ms and the optical responsivity is calculated to be 114 kV/W for a non optimized absorber.

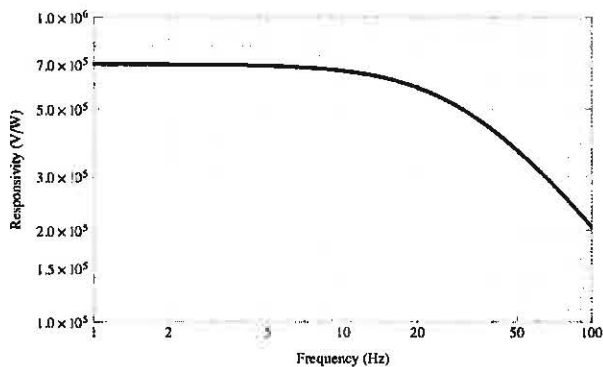


Figure 3. Bolometer reponsivity as a function of frequency to a chopped 763 K blackbody source. The dc responsivity is 702 kV/W .

Voltage Noise Spectra: The voltage noise spectrum, $V_n(f)$, for a resistance $R = 1516\text{ }\Omega$ (close to the mid-point of transition) and current bias $5\text{ }\mu\text{A}$ is shown in Figure 4, together with the measurement system baseline noise. The system noise baseline is established by measuring the voltage noise spectrum when the MgB_2 thin-film is superconducting.

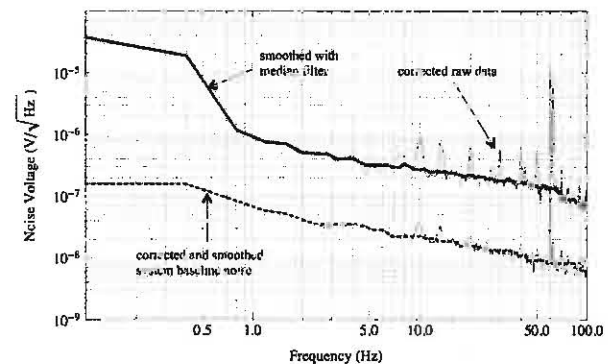


Figure 4. Voltage noise spectra near the mid-point of the superconducting transition at $1516\text{ }\Omega$.

Electrical NEP: In Figure 5, The electrical noise equivalent power, NEP , i.e., $NEP_e(f) = V_n(f) / \mathcal{R}_{v,e}$, is $256\text{ fW}/\sqrt{\text{Hz}}$ at 30 Hz . From this relationship, the optical NEP , i.e., $NEP_o = NEP_e / \eta$ can be calculated for more optimized absorbers [7].

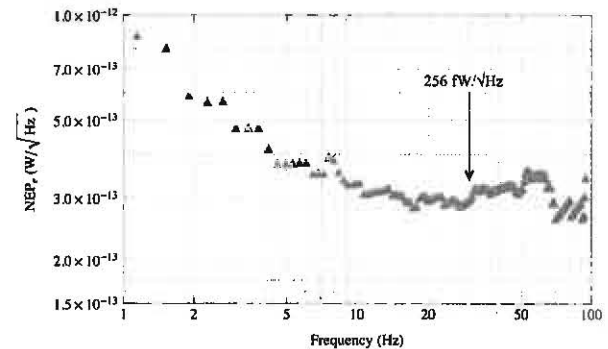


Figure 5. NEP_e as a function of frequency.

References: [1] J. Nagamatsu, et al. (2007) *Nature*, 410, 63. [2] H. Yamamoto et al. (2007) *Physica C*, 463, 948. [3] B. H. Moeckley et al. (2005) *IEEE Trans. on Appl. Supercond.*, 15, 3308. [4] B. Lakew et al. (2006) *Physica C*, 440, 1. [5] S. Aslam, (2008) "Optimization of NEP for MgB_2 bolometers," *private communication*. [6] B. Lakew et al. (2010) *Physica C*,

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